DEVELOPMENT OF ACOUSTIC TEST CRITERIA FOR THE CASSINI SPACECRAFT

Thomas J. Berger, Harry Himelblau, and Dennis Kern
Jet Propulsion Laboratory
California Institute of Technology
Pasadena CA 91109-8099

ABSTRACT

Acoustic measurements from eight Titan IV flights, and an acoustic test of a Cassini simulator and Titan payload fairing (PLF), were used to derive acoustic flight and test criteria for the Cassini spacecraft. The flight and laboratory data were used or modified to account for the following factors: (a) noise spike contamination of flight data, (b) spatial and flight-to-flight variations of flight data, (c) application of a thicker barrier-blanket to the PLF for the Cassini mission, (d) effects of locating two Cassini assemblies, the Huygens Probe (HP) and the High Gain Antenna (HGA), near the PLF, and (e) higher thrust of upgraded Titan solid rocket motors (SRMs) for the Cassini mission. An overall sound pressure level of 1?? dB was verified for the protoflight acoustic test criteria for the Cassini spacecraft.

KEYWORDS: *Cassini spacecraft, Titan IV, payload fairing, flight acoustic data, acoustic test criteria, acoustic blankets, reverberant acoustic test, vibroacoustics*

INTRODUCTION

The Cassini spacecraft, shown in Figure 1, is currently under development at the Jet Propulsion Laboratory (JPL) and its suppliers for the National Aeronautics and Space Administration (NASA) to explore the planet Saturn, its rings and its moons. The spacecraft will be launched by a Titan IV vehicle with a Centaur upper stage. As described in two earlier papers [1,2], acoustic data were acquired on prior Titan flights using the same payload fairing (PLF) to be used on Cassini but, obviously, with different payloads. These data showed that the maximum internal PLF acoustic environment occurred during liftoff and were strongly influenced by the launch pad configuration, e.g., minor differences in acoustic levels were observed between the two similar Titan launch complexes (LC-40 and -41) at Cape Canaveral AFS/Eastern Test Range (ETR) but were substantially exceeded by levels measured at the Vandenberg AFB/Western Test Range (WTR) site (SLC-4E). Since Cassini is scheduled to be launched from LC-41, it was decided to omit WTR data from the database once sufficient ETR data became available.

Like all outer planetary spacecraft, Cassini will require on-board nuclear power because the great distance from the Sun precludes the use of solar power. Specifically, electric power will be provided by three radioisotope thermoelectric generators (RTGs) of essentially identical design to those used on Galileo and Ulysses spacecraft [3,4]. However, the Cassini vibration responses to the acoustic environment at the RTG mountings are expected to exceed those of its predecessors, requiring either RTG redesign and requalification or reduction of the Cassini environment. NASA and JPL concluded that acoustical attenuation would be the most cost effective solution. Thus a program was initiated to reduce the acoustic environment applied to Cassini [5-9]. However, acoustic reduction was required over only a relatively limited portion of the spectrum, namely, the 1/3 octave band (OB) range of 200-250 Hz.

FLIGHT DATA SUMMARY

The previously published summaries included liftoff internal PLF acoustic data from Titan IV Flights K-1 and K-4, both launched from ETR [1,2]. Subsequently, PLF acoustic data were acquired from Flights K-7, -9, -10, -19, -21, and -23 [10-15]. A total of 22 internal PLF acoustic measurements have currently been acquired on these eight flights. Of these, 17 microphones were attached to the PLF, while five were supported off the Centaur forward skirt just below the spacecraft. The 22 measurements include eight repeat measurements on subsequent flights. Three additional K-4 microphones were supported on 20 inch standoffs from the PLF [1,2]. On average, acoustic data from these three standoff microphones were observed to be about 2 dB less than PLF surface data. However, the number of standoff measurements was deemed to be insufficient for the purpose of reducing the acoustic criteria. For this reason, the use of the 22 measurements is considered conservative for the derivation of Cassini acoustic flight and test criteria. Thus, a revised summary of flight data may now be made.

As previously described in [1], liftoff acoustic data from ETR were particularly susceptible to electrical noise spikes. A special procedure was developed to remove the effects of this contamination from data for the first six flights [16], while standard editing methods were used on the last two flights prior to spectral analysis [17].

Figure 2 shows the locations of internal PLF microphones for Flights K-1, -4, -7, -9, -10, -19, -21, and -23 [1, 11-15]. Using an averaging time of 1 sec, 22 maximax acoustic spectra were obtained from these eight flights, as presented in Figures 3 and 4 [1,2] and Figures 5-8, excluding the three standoff microphone spectra. As observed in these figures, measurement locations were repeated in four cases, i.e., Meas. 9727 on Flights K-7, -9, -19, and -23, Meas. 9403 on Flights K-10 and -21, Meas. 9404 on Flights K-10, -21 and -23, and Meas. 973 on Flights K-4, -10, and -21.

Envelopes over the 17 maximax PLF and the 5 maximax Centaur acoustic spectra were drawn, resulting in the heavy lines of Figures 9 and 10. Statistical analyses were also performed on all 22 spectra. Figure 11 shows the mean value and 95 percent upper tolerance limit, with 50 percent confidence, based on statistical analysis of the 22 spectra of Figures 9 and 10, assuming a normal distribution of sound pressure levels (SPLs) for each 1/3 OB. For these 22 samples, a tolerance factor of k = 1.669 was used [1,2]. The use of P95/50 statistics for deriving vibroacoustic criteria from flight data has been a USAF and NASA tradition for many years.

In addition to flight activities, a series of laboratory acoustic tests were performed. Data from these tests were used in the development of acoustic test criteria as summarized in the following section.

ACOUSTIC TEST DATA SUMMARY

Flat Panel Results

A test program was initiated to determine if an increase in acoustic blanket thickness and/or the addition of a sound barrier could achieve the desired reduction of acoustic loading applied to Cassini and its RTGs. An elaborate series of flat panel tests were first implemented to determine if either or both of these solutions could produce the needed attenuation of 3 dB or more in the 200-250 Hz bands [6]. Historically, testing was necessary because the application of acoustic theory to this problem was severely limited due to an inability to account simultaneously for twin factors of sound absorption and transmission. Flat panel results indicated that only two of the tested configurations could achieve the desired reduction:

(a) A 6 in. blanket having a density of 0.6 lb/ft³ plus a 0.043 in. barrier having a surface density of 0.44 lb/ft², for an overall surface density of 0.74 lb/ft².

(b) A 5 in. blanket comprised of 3 in. having a density of 0.6 lb/ft³ and 2 in. having a density of 1.2 lb/ft³, plus a 0.083 barrier having a surface density of 0.88 lb/ft², for an overall surface density of 1.28 lb/ft².

The standard Titan IV 3 in. blanket having a density of 0.6 lb/ft³, for an overall surface density of 0.15 lb/ft², was also included since blankets of this design were installed during flights when acoustic measurements were made. Sketches of the three blankets are shown in Figure 12.

Unfortunately, the attenuation was needed in the frequency range (200-250 Hz) dominated by the ring frequency of the cylindrical portion of the PLF. Thus there was no guarantee that flat panel results would be directly applicable to the Cassini installation. As a result, a series of PLF tests was deemed necessary to demonstrate that adequate reduction was achievable under realistic Cassini conditions.

Cassini Simulator/PLF Reverberant Test Procedure

Fortunately, the timing of PLF blanket tests coincided with vibroacoustic testing of the Cassini partial development test model (DTM), the simulator shown in Figure 13, which simultaneously permitted the determination of acoustic attenuation effects on the structural response of spacecraft and component simulators [18,19]. Unlike the partial-DTM test in its PLF, the forthcoming protoflight acoustic test on the actual Cassini spacecraft in the JPL reverberant chamber will not utilize a PLF. Thus special attention is required to account for acoustic loads expected to cause higher spacecraft vibration response, especially loads applied to the Huygens Probe (HP) and the High Gain Antenna (HGA) as determined from partial-DTM/PLF testing. In addition to determining the acoustic transmission/absorption of the 3-, 5-, and 6 in. blanket configurations, the other objectives of partial-DTM testing included:

(a) Evaluation of the effects of having the HP and other Cassini elements in close proximity to the PLF.

(b) Determination of the effects of having the HGA separate the biconic section from the cylindrical section of the PLF.

(c) Determination of the effects of percentage blanket coverage on acoustic attenuation.

(d) Evaluation of the effects of tuned vibration absorbers (TVAs) on the structural response of the RTGs.

The Cassini partial-DTM was installed in a 60 ft long section of the PLF, along with a Centaur-like support structure, and the blanket configuration to be tested attached to the PLF interior for the specified acoustic test run, as shown in Figure 13. This assembly was installed in the Reverberant Acoustic Laboratory facility located at Lockheed-Martin Astronautics in Denver, CO [18], where acoustic noise from air modulators was applied to the PLF exterior. A list and sketch of the 8 exterior and 27 interior microphone locations appears in Table I and Figure 13, respectively. A total of 72 accelerometers and 3 triaxial force gages were also installed on or in the Cassini partial-DTM structure. Data from some of these transducers has been reported elsewhere [5,9,18,19].

Both 5- and 6-in. blanket configurations were found to provide the desired acoustic reduction. The 6 in. barrier blanket was selected over the 5 in. configuration since it carries less added weight to the PLF. For this reason the test results for the heavier configuration, including the effects of partial coverage, will not be reviewed here. For the Cassini mission, it was intended that the thicker barrier-blanket be installed on the PLF interior in the vicinity of the major portion of the spacecraft only rather than complete PLF coverage, in order to save weight while still being locally effective. Thus the 6 in. configuration would be used in PLF Zones 8-11 (Figure 14), while the 3 in. blanket would continue to be used in Zones 2 to 7.

Although somewhat similar in general, there are important differences between the acoustic environments applied to the PLF exterior during flight and during a reverberant acoustic chamber test. Also, there is some variability between reverberant test runs identified in Figure 14, mainly because of difficulties in achieving perfect acoustic test control. To avoid having potential errors influence (a) the evaluation of the 6 in. barrier-blanket, and (b) the prediction of the flight acoustic environment using the thicker configuration, the following step-by-step procedure was used in processing the measured acoustic data:

(1) For each test run, all microphone data were analyzed twice, first using a constant resolution bandwidth of 4 Hz up to 2 kHz, and then using 1/3 OBs with center frequencies ranging from 31.5 Hz to 4 kHz.

(2) For each run, the average 1/3 OB SPL, plus the overall (OA) SPL, for the six external control microphones (M30-M35 in Table I) was computed for each 1/3 OB, and the difference taken between this average and the external acoustic test specification shown in Figure 15. This difference is called the external correction.

(3) For each run, the 1/3 OB SPLs from 15 internal microphones located in Zones 7-11 (M1, 6, 8, 10, 1?, 14, 16, 17, 19, 20, 2?-?(1) were averaged and adjusted using the external correction of Step 2. The average 1/3 OB SPLs are called the internal adjusted spectrum for that run.

(4) To predict the additional acoustic attenuation of a thicker configuration (e.g., the 6 in. barrier-blanket), the difference was taken between the internal adjusted acoustic spectra of Step 3 for the applicable pair of test runs, i.e., (a) the original 3 in. flight blanket configuration of Test 2, and (b) the 6 in. barrier-blanket of Test 7.

(5) To establish the revised Cassini flight acoustic criteria using the thicker configuration, the difference of Step 4 was subtracted from the original P95/50 flight acoustic criteria shown in Figure 11.

Experience has shown that acoustic fill effects can cause a substantial increase in the local acoustic environment applied to structural assemblies which are close to the PLF [19]. The HP is the closest of these assemblies, being approximately 34.1 in. from the PLF surface (excluding the blanket thickness). The two methods of determining fill effect are (a) an analytical formula derived from a recently revised theory [19], and/or (b) the direct measurement of the SPLs in the gap using a microphone.

As seen in Figure 13, the Cassini HGA effectively separates the biconic section of the PLF from the cylindrical section, i.e., separating the PLF cavity into two volumes. Thus it would not be surprising to find two distinct acoustic environments for these volumes, both of which apply fluctuating pressure to opposite sides of the HGA with the structural loading dependent on the pressure cross spectrum across the HGA. Figure 16 shows coherence data, i.e., the normalized magnitude of the cross-spectrum [21-23], for a microphone pair on opposite sides of the HGA close to the structure, i.e., M4 and M6 in Figure 13. The data shows low coherence (except at 43 Hz), which indicates that the two acoustic fields act independently and the two spectra should be root sum squared. At 43 Hz, the coherence is fairly high ($\gamma^2_{4,6} \approx$ 0.8) and the phase angle is nearly zero, indicating the instantaneous pressures should be subtracted and the loading reduced.

Cassini Simulator/PLF Reverberant Test Results

The raw acoustic test data was processed in accordance with Step 1-5 to provide the desired revision to the Cassini flight acoustic criteria. Figure 17 shows the internal adjusted spectra for the two test runs of interest: (a) Test 2 where the 3 in. flight blankets were utilized, and (b) Test 7 where the 6 in. barrier-blankets were installed in Zones 8-11 and the 3 in. blankets in Zones 2 and 7. The additional acoustic attenuation provided by the thicker configuration was obtained by taking the difference between the Test 7 and Test 2 internal adjusted spectra, as shown in Figure 18. This difference was then subtracted from the P95/50 flight spectrum of Figure 11 (obtained from the statistical data analysis of 22 flight measurements from eight previous flights) in order to predict the Cassini P95/50 internal flight spectrum shown in Figure 19.

To determine the fill effect for the Huygens Probe, Microphone 11 was located in the 28 in. gap between the center of the HP and the PLF during the entire test series except for Test 1 and 8 where no spacecraft simulator was used. Unfortunately M11 malfunctioned during Test 7 making a direct measurement impossible. Fortunately, the revised analytical fill theory [20] could be substituted. Moreover, the general accuracy of this theory could be ascertained for the HP using M11 data from Tests 4 and 5 with the 5 in. barrier-blanket, which had very similar acoustic attenuation characteristics to the 6 in. configuration but was not selected due to excessive weight. Figure 20 shows the comparison between the analytical effect and the appropriate data from Tests 4 and 5. The comparison is generally satisfactory with important exceptions below 50 Hz and at 2.5 kHz. At low frequencies, the exception was probably caused by insufficient modal density, i.e., a low number of modes (including zero!), which violates a critical assumption of statistical energy analysis (SEA) used in the fill effect derivation. It is speculated that a dominant standing wave may have been encountered in the high frequency band. Despite these exceptions, it was decided to accept the analytical fill effect in deriving the Cassini acoustic test criteria.

As observed in Figure 13, the HGA effectively divides the PLF cavity into two volumes, i.e., the biconic section above and the cylindrical section below the HGA. The flight acoustic data reviewed previously were acquired at locations in the cylindrical section only. Thus it was necessary to obtain acoustic data in both sections during the Partial-DTM/PLF test to ascertain if higher or lower SPLs existed in the biconic section. If higher levels were found, then an increase in the Cassini acoustic test criteria would be justified over that determined from previous flight data. For application to Cassini spacecraft acoustic testing, data for the two acoustic fields from Test 7 were compared. Spectra for the three microphones within the biconic section (M2-4) were averaged and compared with the spectral average from 15 microphones in the cylindrical section, as shown in Figure 21. The difference between the two average spectra is shown in Figure 22 along with the analytical HP fill factor. Acoustic undertesting of the Cassini spacecraft will be avoided by increasing the P95/50 flight spectrum of Figure 11 by the difference obtained from the maximum envelope of the two curves shown in Figure 22. The avoidance of HGA under- or over-testing is also dependent on the pressure cross-spectrum across opposite sides of the HGA during the forthcoming Cassini spacecraft acoustic test.

CASSINI SPACECRAFT ACOUSTIC TEST CRITERIA DERIVATION

In order to provide more thrust to the Titan IV vehicle, which is required to permit the launch of the heaviest possible spacecraft propellant mass, the previously-used standard steel case solid rocket motors (SRMs) will be replaced by recently-developed more powerful (7 percent) composite case SRM upgrades (SRMUs). This change is predicted to result in a small increase in acoustic levels, less than 1 dB, which must be taken into account before the revised Cassini flight criteria and the Cassini spacecraft acoustic test criteria are derived.

In summary, the flight acoustic criteria, as well as the test criteria for the forthcoming Cassini spacecraft acoustic test without the PLF, were derived using:

(1) the P95/50 internal PLF flight spectrum of Figure 11, which was computed by the statistical data analysis of 22 maximax acoustic spectra (shown in Figures 3-8) from eight previous flights,

(2) minus the difference between Test 7 and Test 2 internal adjusted spectra (shown in Figure 18) to account for the thicker barrier-blanket attenuation,

(3) plus a 1 dB increase for using the SRMUs for the Cassini mission, resulting in the revised Cassini flight acoustic criteria of Figure 23,

(4) plus the maximum of (a) the HP analytical fill effect, and (b) the difference between the two average acoustic spectra across the HGA, both shown in Figure 22,

(5) plus minor "adjustments" needed to provide a smooth test spectrum required by high intensity noise generators, such as air modulators, resulting in the revised acoustic criteria for the Cassini spacecraft test shown in Figure 24.

CONCLUSIONS

Acoustic measurements from eight Titan IV flights, and an acoustic test of a Cassini simulator and Titan payload fairing (PLF), were used to revise acoustic flight and test criteria for the Cassini spacecraft. The derived flight and FA test criteria have overall SPLs of 140.5 and 141 dB, respectively. The revised flight criteria will be compared with flight data obtained during the actual Cassini launch. The revised test spectrum has been compared with the previous test criteria, also shown in Figure 24. The revised spectrum exceeds the previous criteria in only two bands, 31.5 and 40 Hz, with a maximum exceedance of 1.5 dB at 40 Hz. This exceedance is caused by a single flight measurement, namely Mic 9404 on Flight K-23. Repeated measurements at the same location on two other flights show substantially lower levels. Thus this exceedance is deemed to be an artifact of the particular circumstances and not indicative of the overall flight process. The previous test spectrum will be used as reverberant acoustic test levels during the flight spacecraft acoustic test without the PLF with a protoflight margin of 4 dB over the FA levels shown in Figure 24.

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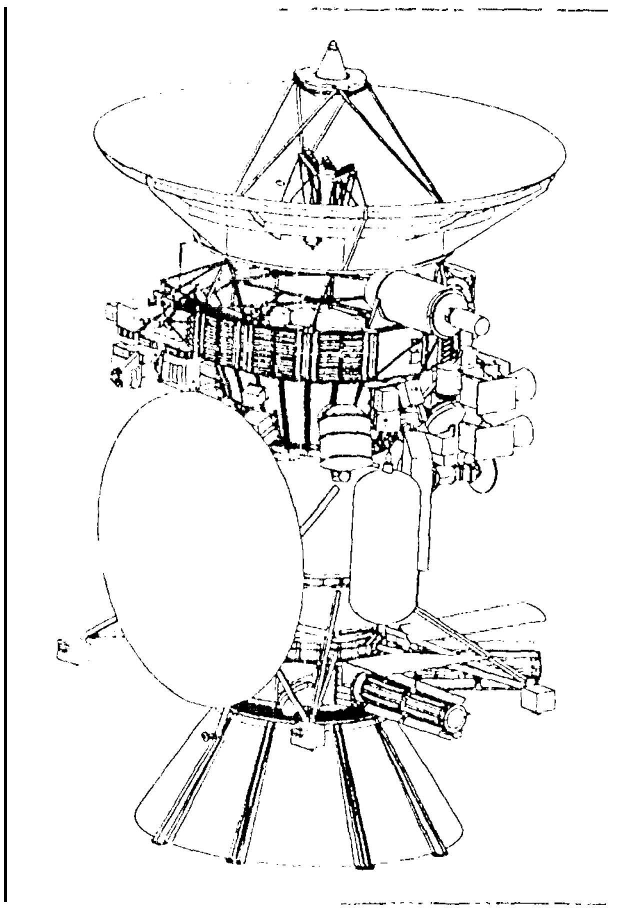


Figure 1: Trimetric View of the Cassini Spacecraft in its Launch Configuration

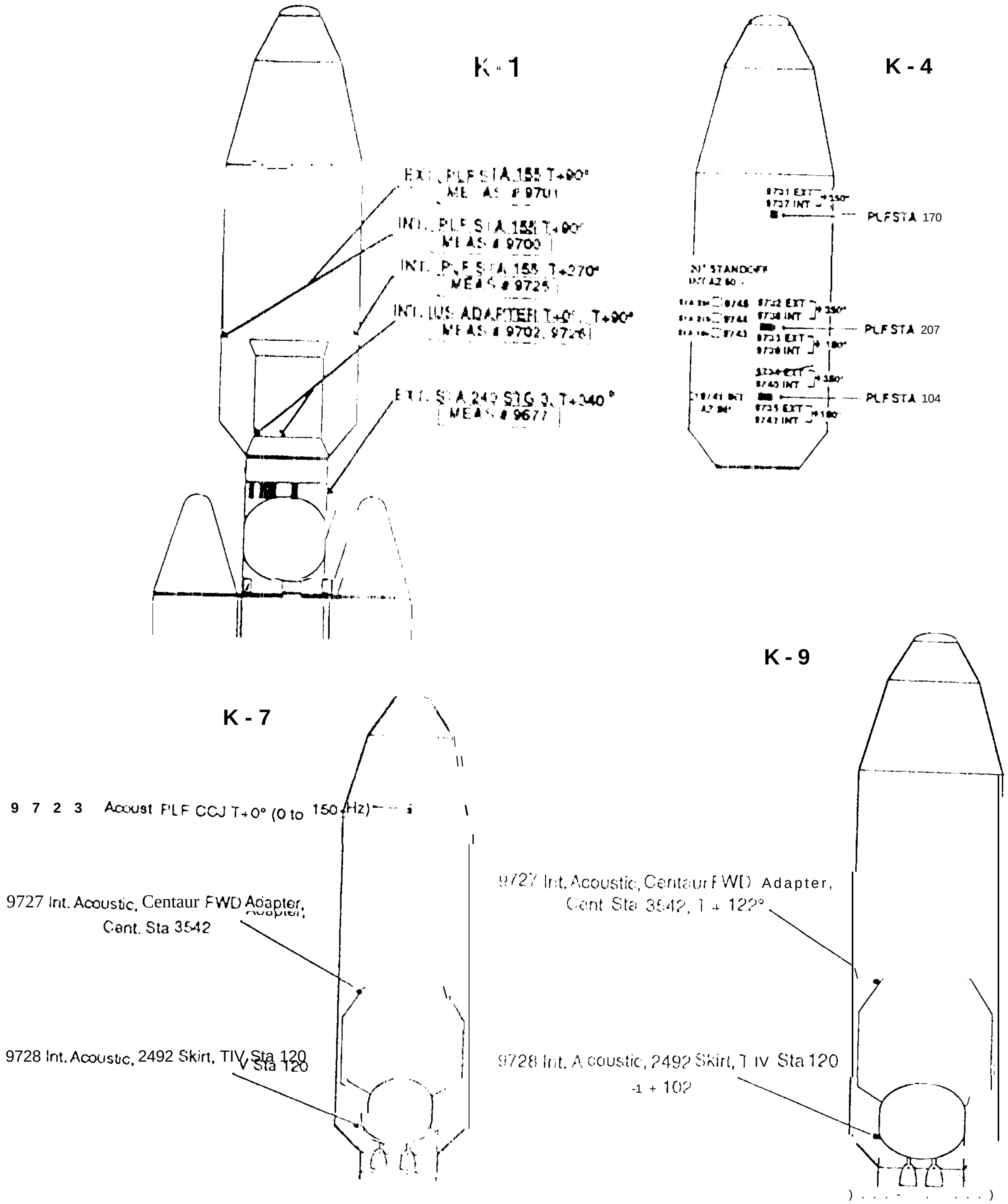


Figure 2: Location of Microphones Used on Eight Titan IV Flights to Derive Cassini Acoustic Criteria

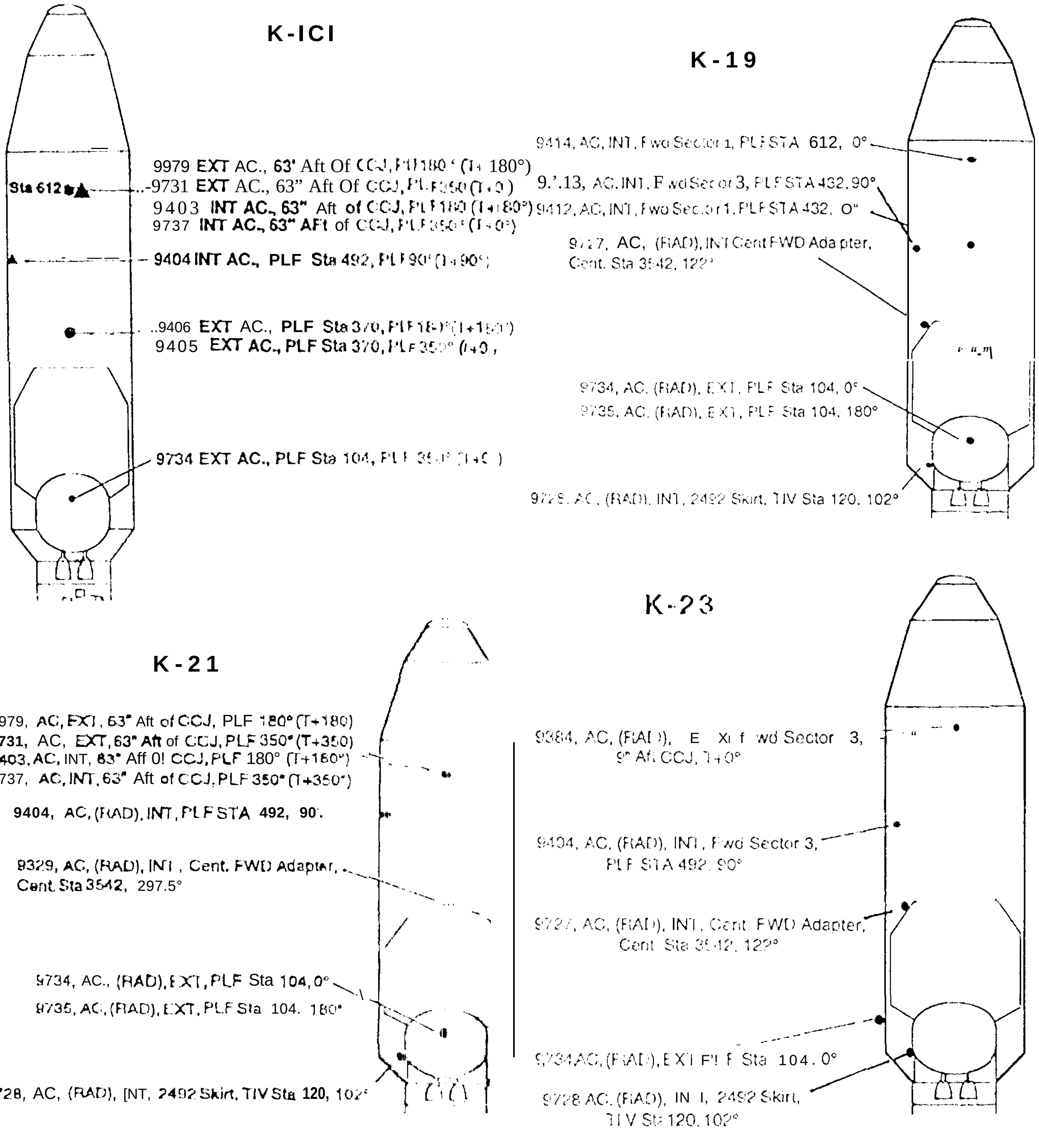


Figure ? (continued)

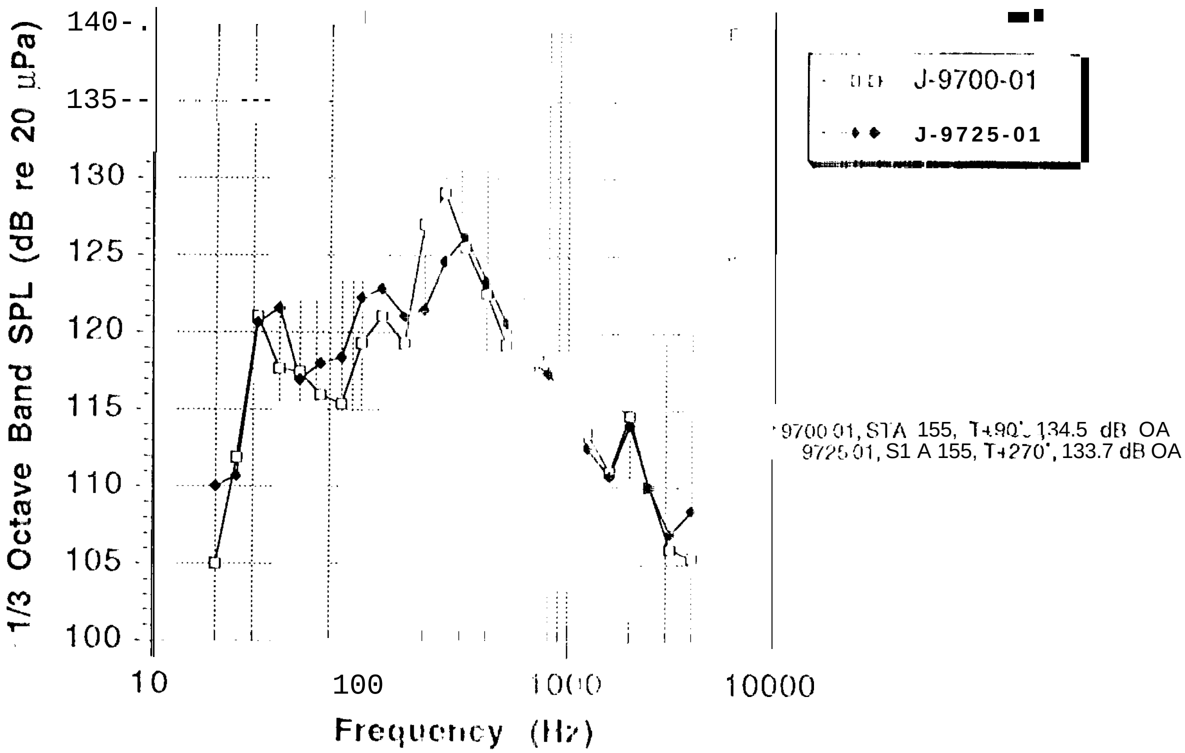


Figure 3: Maximax Acoustic Spectra for Flight K-1 Internal Payload Fairing Measurements During Liftoff

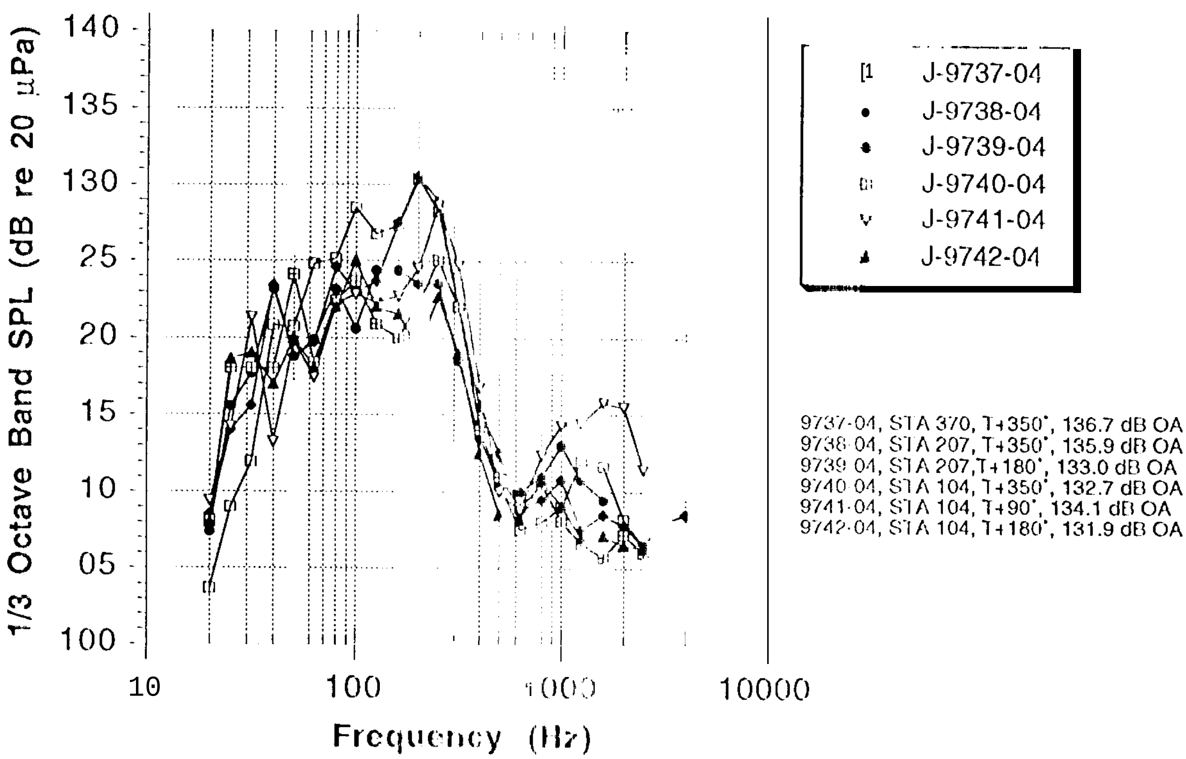


Figure 4: Maximax Acoustic Spectra for Flight K-4 Internal Payload Fairing Measurements During Liftoff

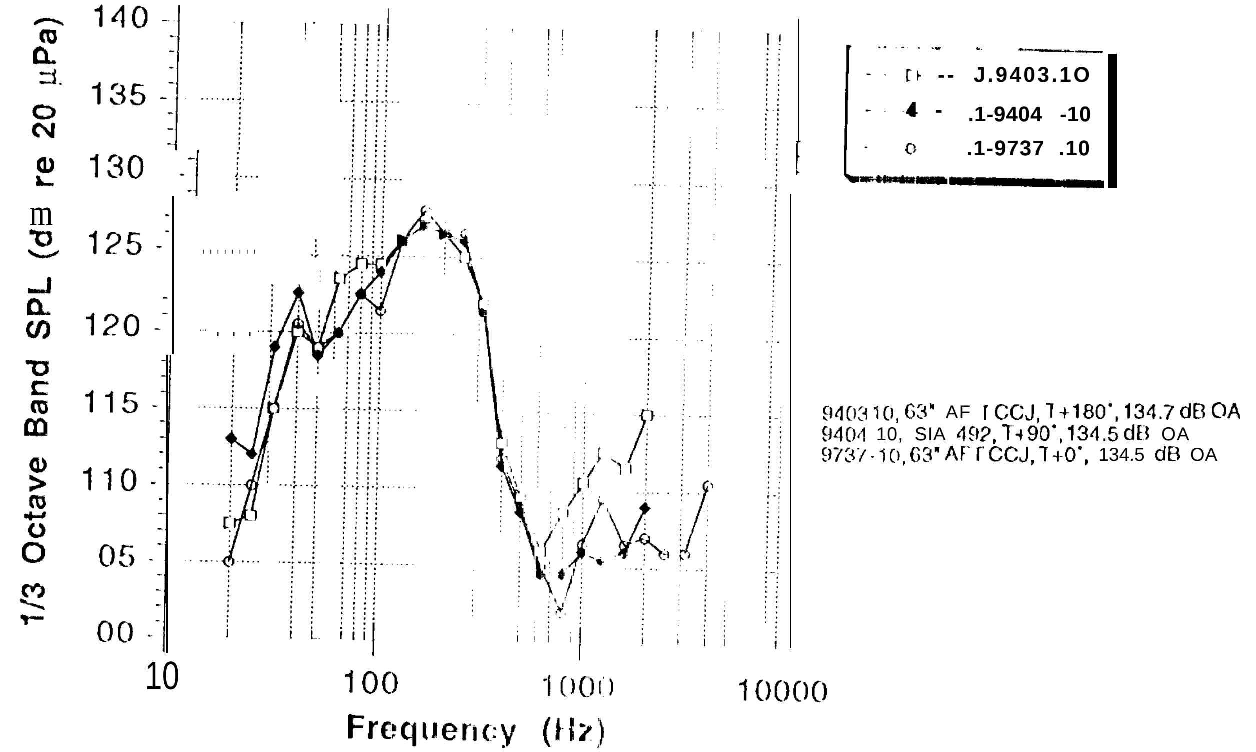


Figure 5: Maximax Acoustic Spectra for 1 light K10 Internal Payload Fairing Measurements During Liftoff

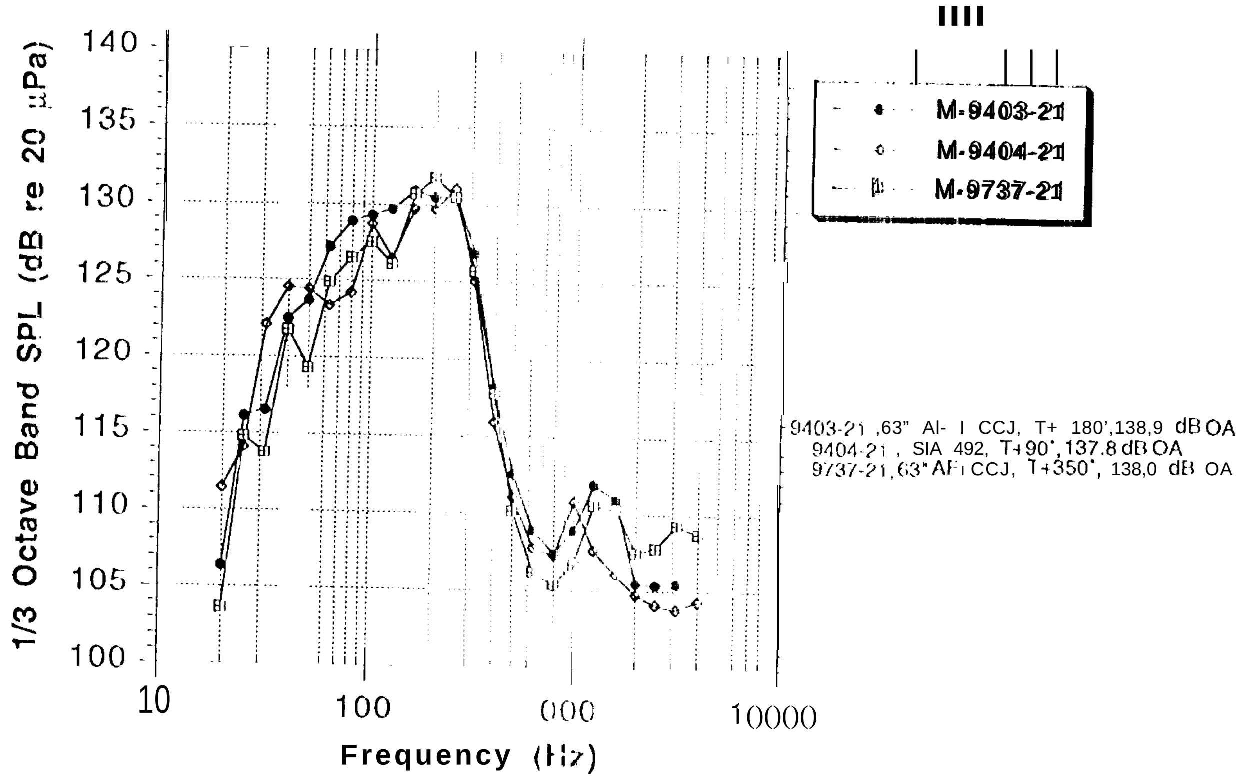


Figure 6: Maximax Acoustic Spectra for Flight K-21 Internal Payload Fairing Measurements During Liftoff

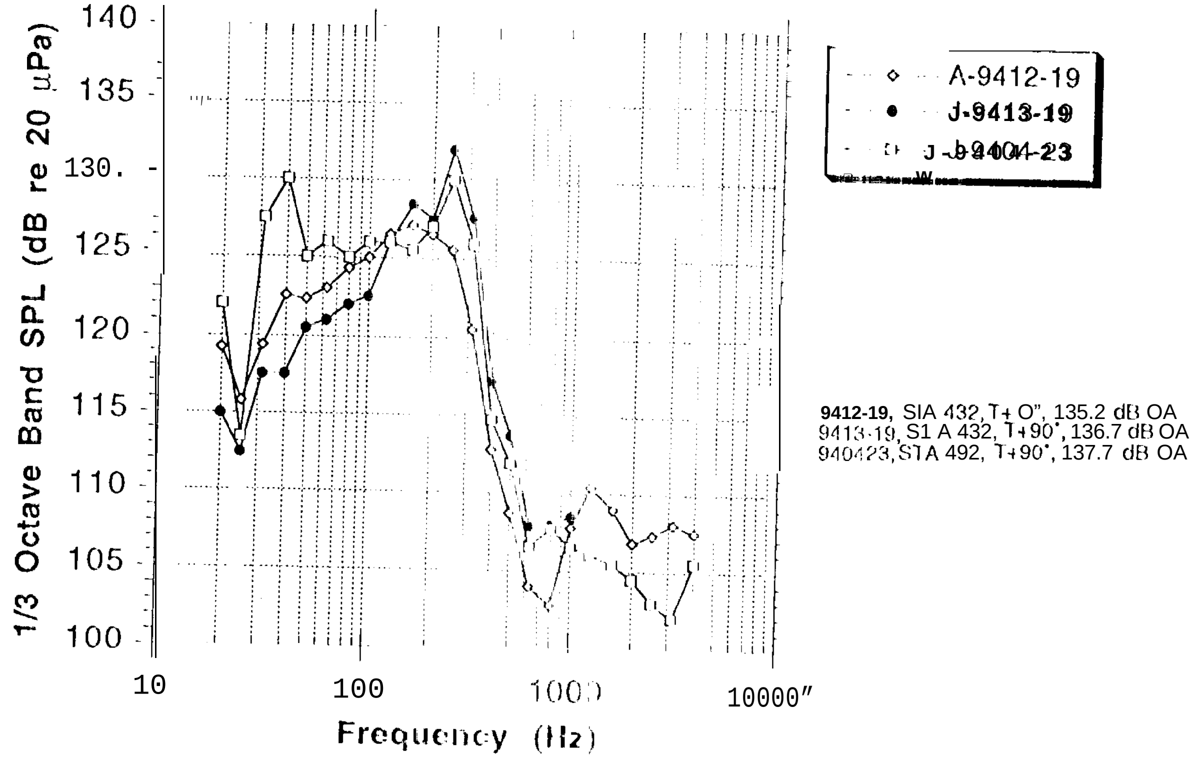


Figure 7: Maximax Acoustic Spectra for Flights K-19 and K-23 Internal Payload Fairing Measurements at Liftoff

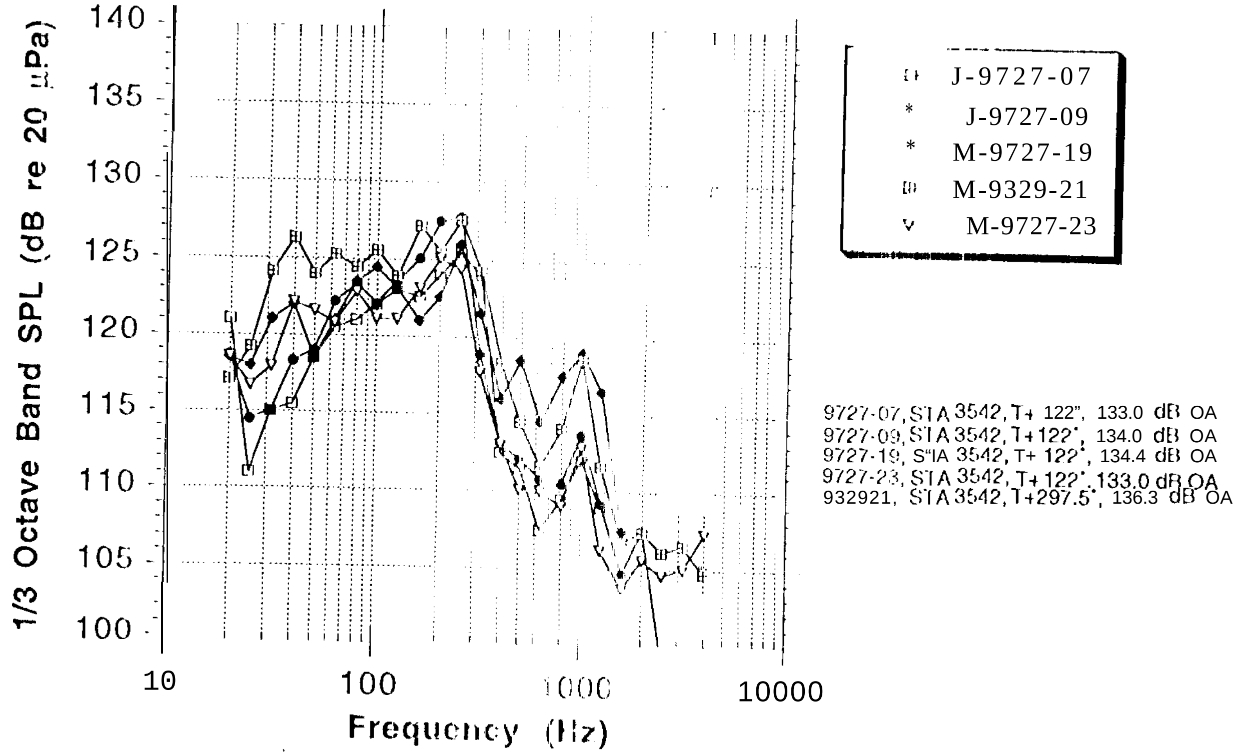


Figure 8: Maximax Acoustic Spectra for Flights K-7, -9, -19, -21, and -23 Internal Centaur Forward Adapter Measurements During Liftoff

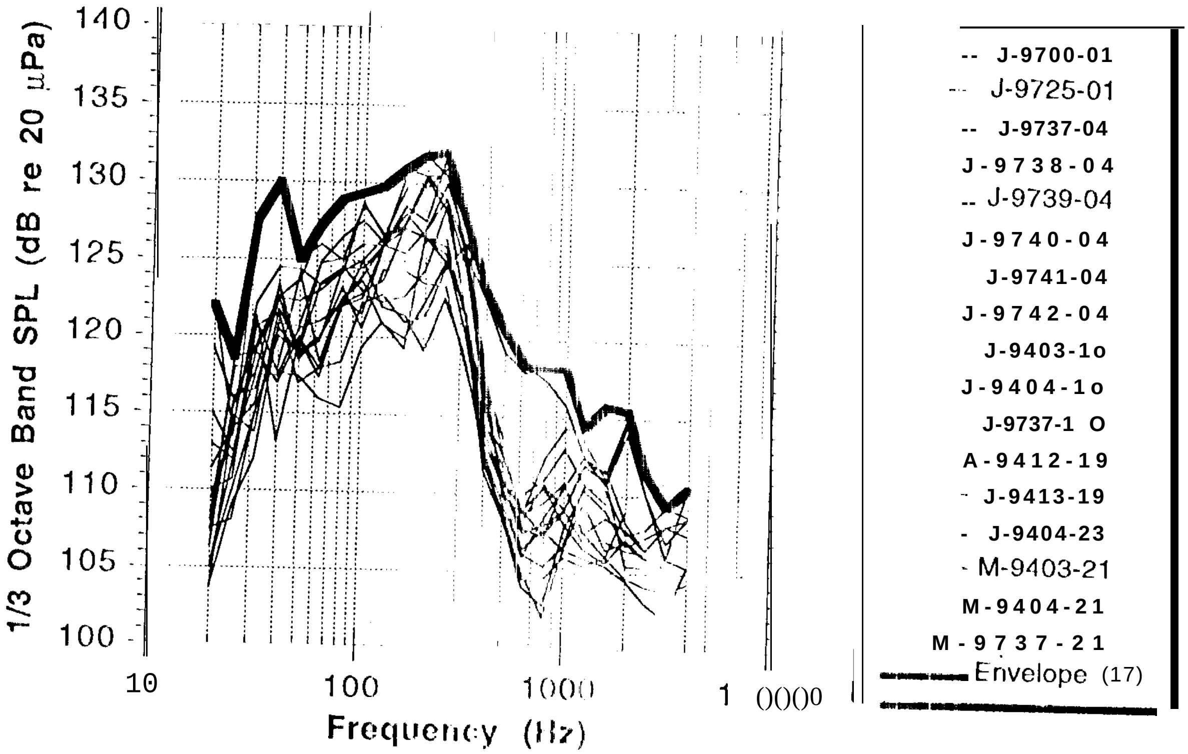


Figure 9: Spectral Envelope of Maximax Acoustic Spectra for 17 Internal Payload Fairing Measurements During Liftoff of Six Flights

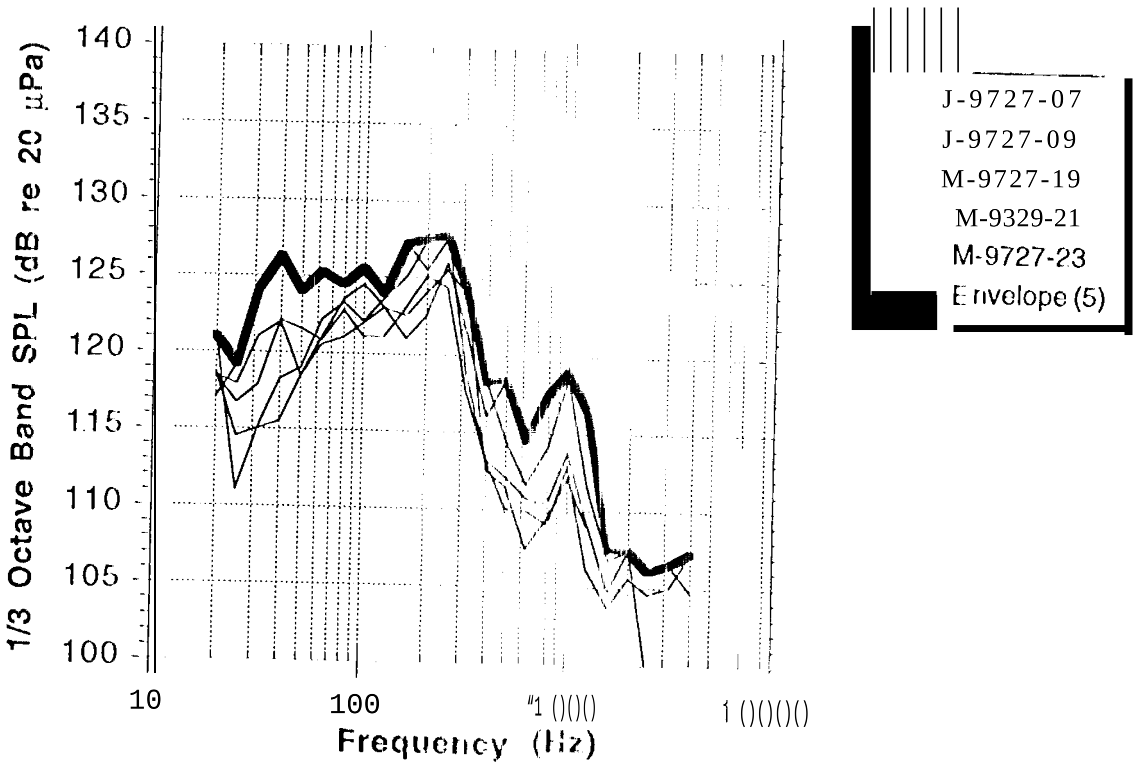


Figure 10: Spectral Envelope of Maximax Acoustic Spectra for Five Internal Centaur Measurements During Liftoff of Five Flights

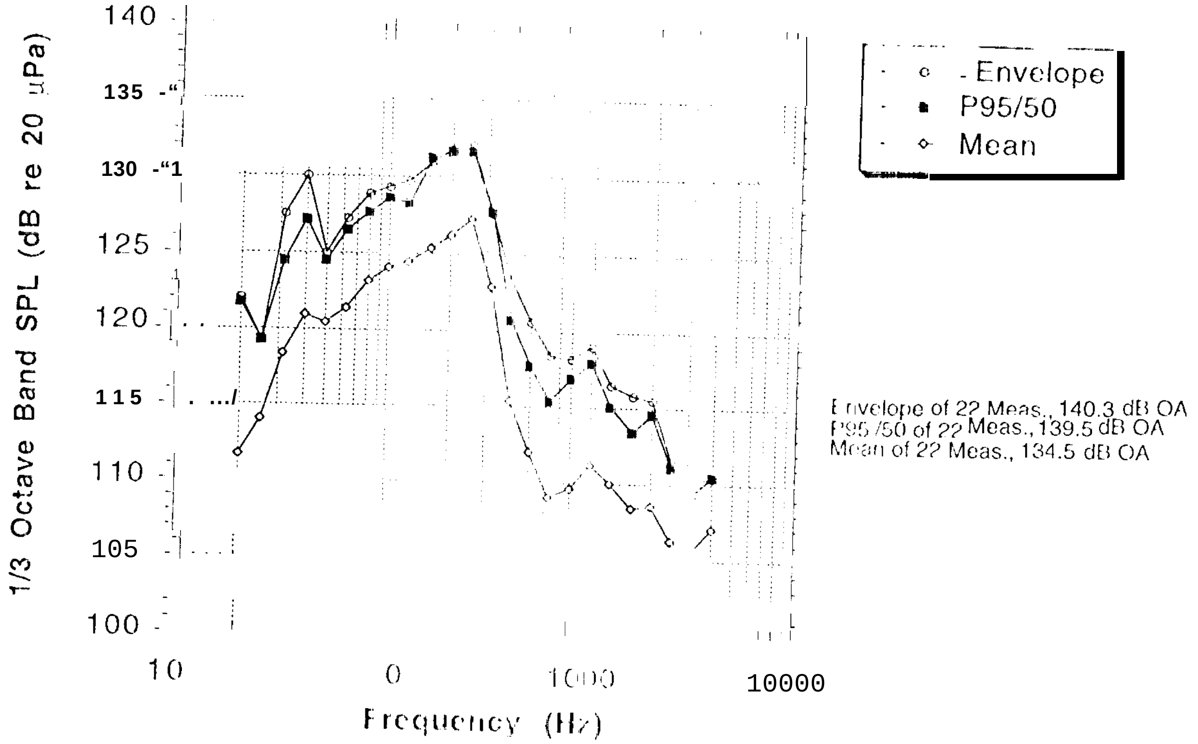


Figure 11: Comparison of Mean, P95/50%, and Spectral Envelope of Maximax Acoustic Spectra for 22 Internal Payload Fairing/Centaur Measurements from Eight Titan IV Flights

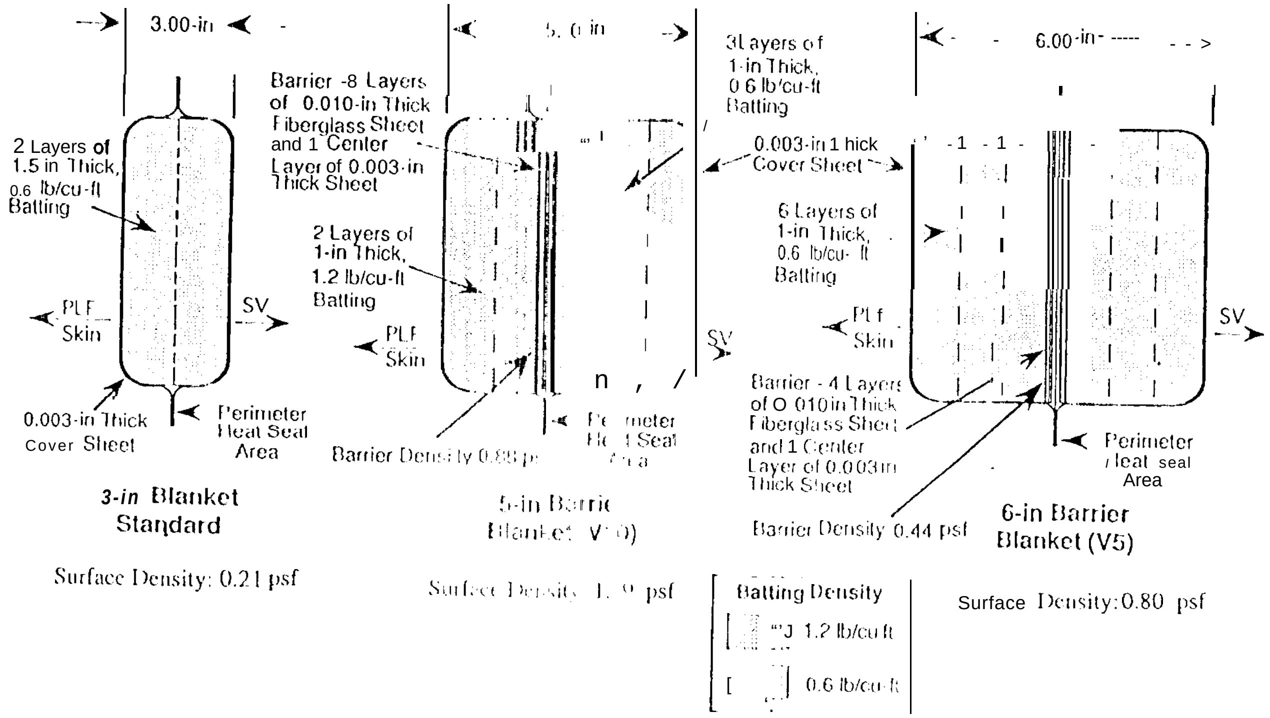
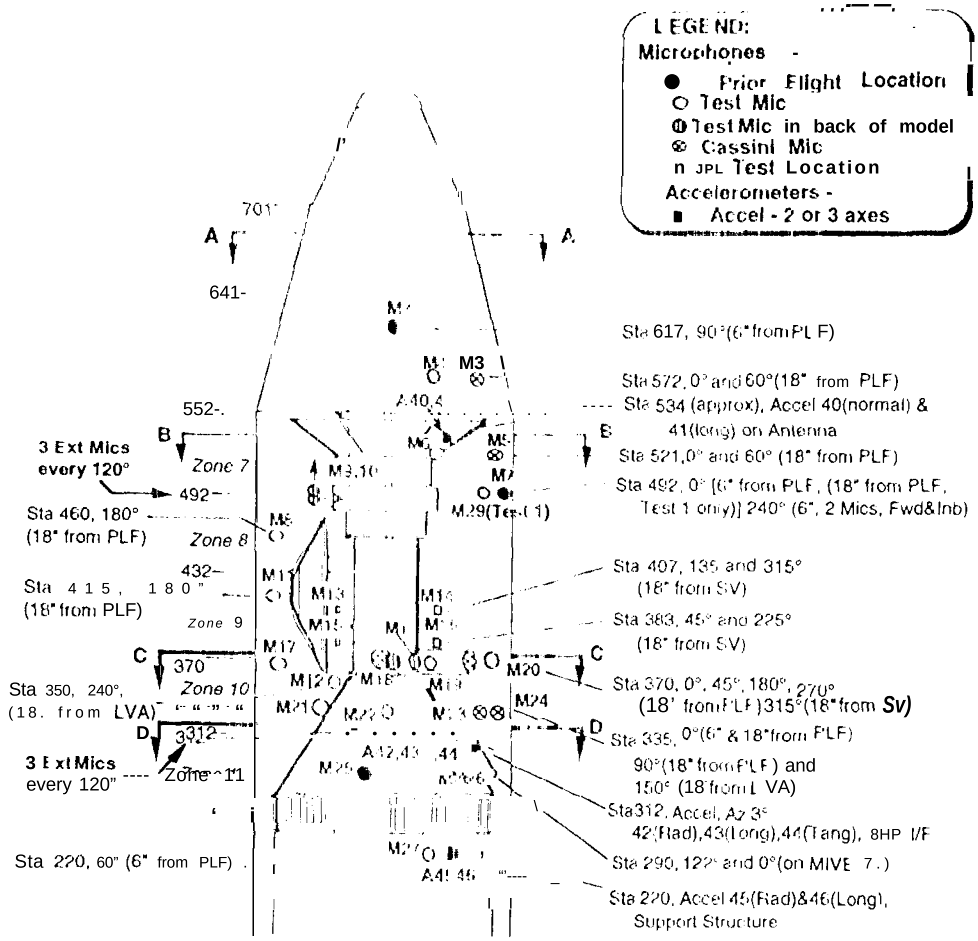


Figure 12: Titan IV PLF Acoustic Blanket Configurations

Table 1: Microphone Instrumentation Summary for the Partial DTM/PLF Acoustic Tests

MIC NO.	Cassini PLF STA	PLF AZ	DISTANCE From Structure	COMMENTS
M1*	371	300	6" from DTM	RTG mapping
M2	612	90	6" from PLF	K5, K8
M3	572	0	18" from PLF	Cassini Mic
M4	572	60	18" from PLF	
M5	521	0	18" from PLF	Cassini Mic
M6	521	60	18" from PLF	
M7	492	355	6" from PLF	K4, K8, K10
M8	460	180	18" from PLF	
M9	492	240	6" from PLF	Directed Forward
M10	492	240	6" from PLF	Directed Inboard
M11	415	180	18" from PLF	High Fill
M12*	350	240	18" from PLA	18" from Payload Adapter
M13*	407	135	18" from DTM	JPL Test/RTG mapping
M14*	407	315	18" from DTM	JPL Test/RTG mapping
M15*	383	225	18" from DTM	JPL Test/RTG mapping
M16*	383	45	18" from DTM	JPL Test/RTG mapping
M17	370	180	18" from PLF	RTG mapping
M18	370	265	18" from PLF	RTG mapping
M19	370	45	18" from PLF	RTG mapping
M20	370	0	18" from PLF	RTG mapping
M21*	335	162	18" from PLA	High Blnkt Cover
M22	322	80	18" from PLF	Low Blnkt Cover (Door)
M23	335	0	18" from PLF	Cassini Mic
M24	335	0	6" from PLF	Cassini Mic
M25	290	122	[illegible]" from Cent Adapt.	K7, K9
M26	290	0	[illegible]" from Cent Adapt.	
M27	230	60	6" from PLF	Unblanketed, High Fill
M28	370	Centerline	100" from PLF	Test 1 Only - Centerline MIC
M29	492	0	18" from PLF	Test 1 Only - paired with M7
M30	492	0	EXT. 18" from PLF	Control
M31	492	120	EXT. 18" from PLF	Control
M32	492	240	EXT. 18" from PLF	Control
M33	312	0	EXT. 18" from PLF	Control
M34	312	120	EXT. 18" from PLF	Control
M35	312	240	EXT. 18" from PLF	Control
M36	808	Centerline	EXT. 18" from PLF	Centered above Tip of Nose
M37	132	180	EXT. 18" from PLF	

Note 1: Microphones marked with one asterisk will not be included in Test 1
Note 2: Microphones M28 and M29 will be used on Test 1 only.
Note 3: All PLF mounted Mics directed radially inboard except Mic 9, which is directed forward
Note 4: Mics 13, 14, 15, 16 directed radially inboard (facing DTM), all other Mics mounted on internal structures mounted radially outboard, except Mic 27, directed radially inboard.
Note 5 Mic 28 (centerline) directed forward (upward).



Note 1: On Test No. 1, M28 will be positioned on the centerline above the MIVE at approximately PLF Sta 510

Note 2: M29 will be used on Test No. 1 only

Note 3: Station Numbers are referenced to Cassini PLF Station Numbers

Figure 13: Configuration and Instrumentation Locations for the Partial DTM/PLF Acoustic Tests

Test No.	Blankets	Coverage	P/L Simulator
1	3-in Std	Full	No
2	3-in Std	Full	Yes, w/ VAS
3	3-in Std	Partial	Yes, w/ VAs
4	5-in V-10	Full	Yes, w/ VAs
5	5-in V-10	Full	Yes, w/o VAs
6	5-in V-10	Partial	Yes, w/o VAs
7	6-in V-5	Full	Yes, w/o VAS

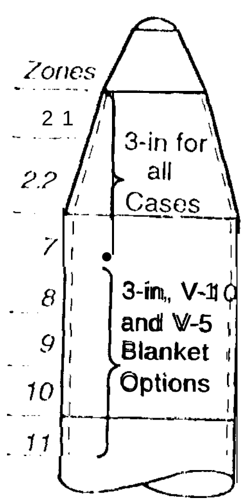
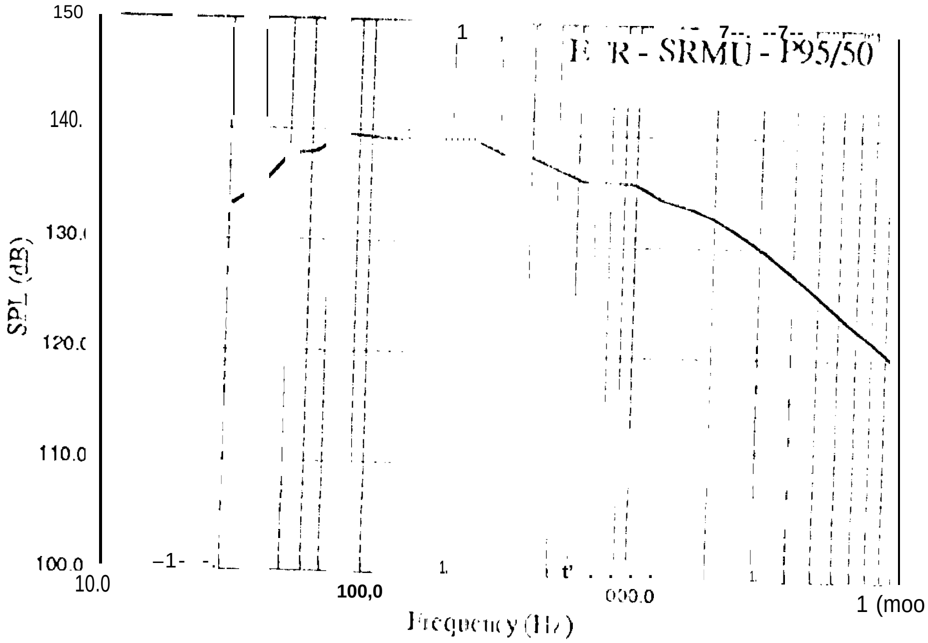


Figure 14: Partial DTM/PLF Acoustic Test Cases



Freq	SPL
31	133.2
40	135.0
50	137.7
63	138.0
80	139.6
100	139.4
125	139.2
160	139.3
200	139,3
250	139,1
315	138.0
400	137.9
500	136,9
630	135.9
800	135,9
1000	135.7
1250	134.4
1600	133.7
2000	132.8
2500	131.4
3150	1298
4000	127.8
5000	125.8
6300	123.8
8000	121.8
10000	119.8
OASPL:	150.4

Figure 15: External Acoustic Test Levels for the Partial DTM/PLF Acoustic Tests

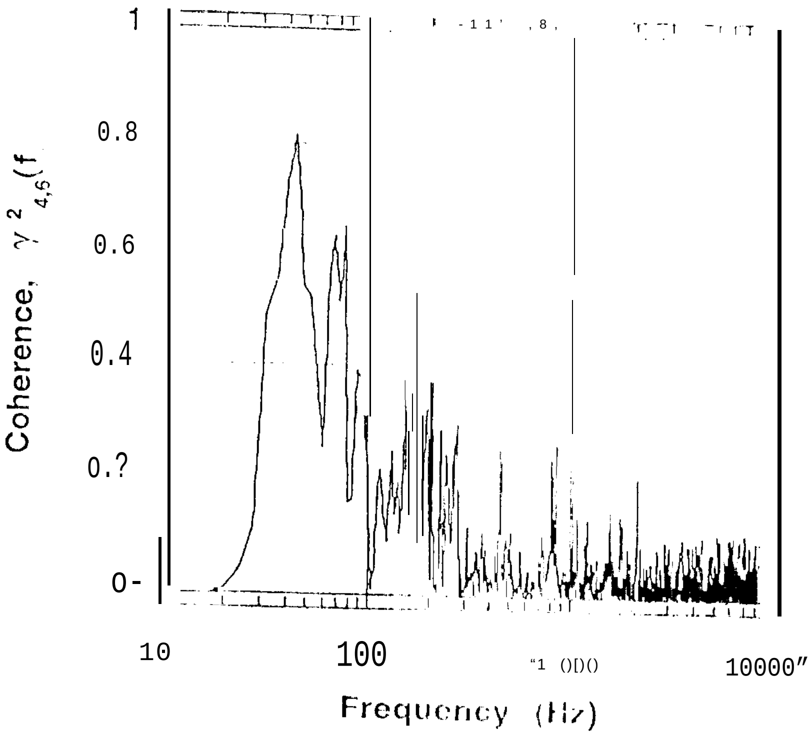


Figure 16: Coherence Spectrum for Microphones 4 and 6 on Opposite Sides of the Cassini High Gain Antenna During Reverberant Acoustic Test 7 of the Partial DTM/PLF

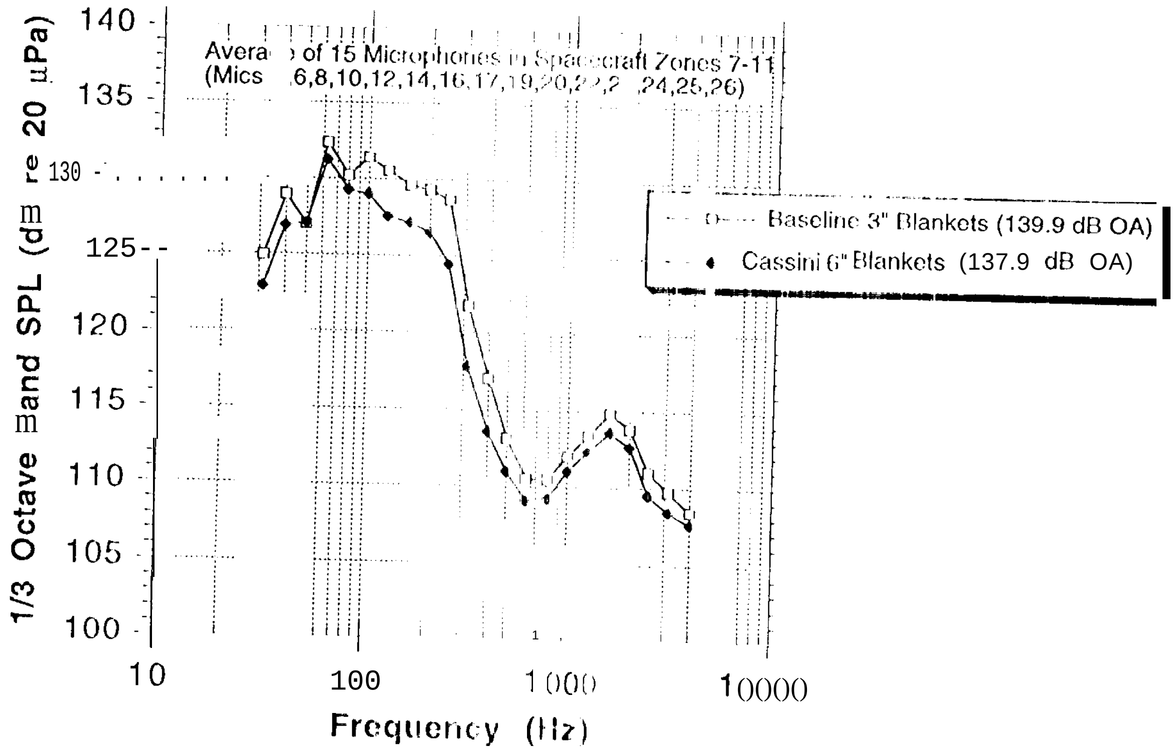


Figure 17: Comparison of Average Acoustic Level Around the Spacecraft Measured During Tests 2 and 7

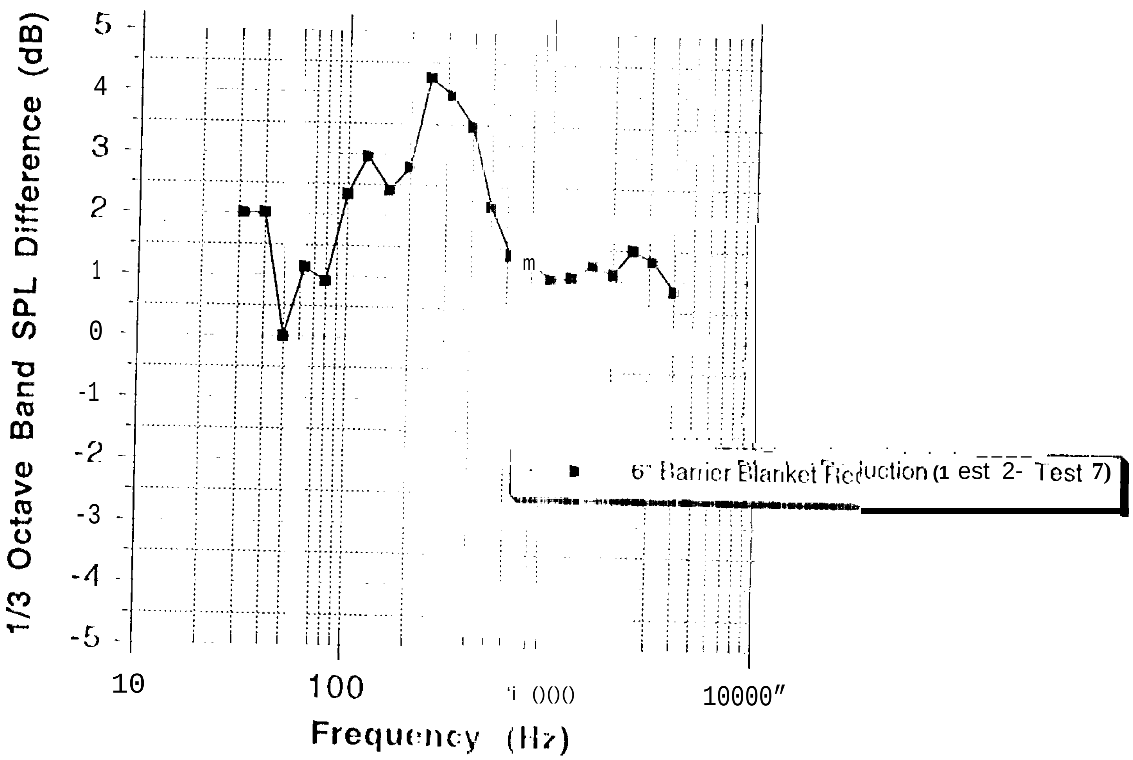


Figure 18: Difference of Average Acoustic Spectra Around the Spacecraft Measured During Tests 2 and 7

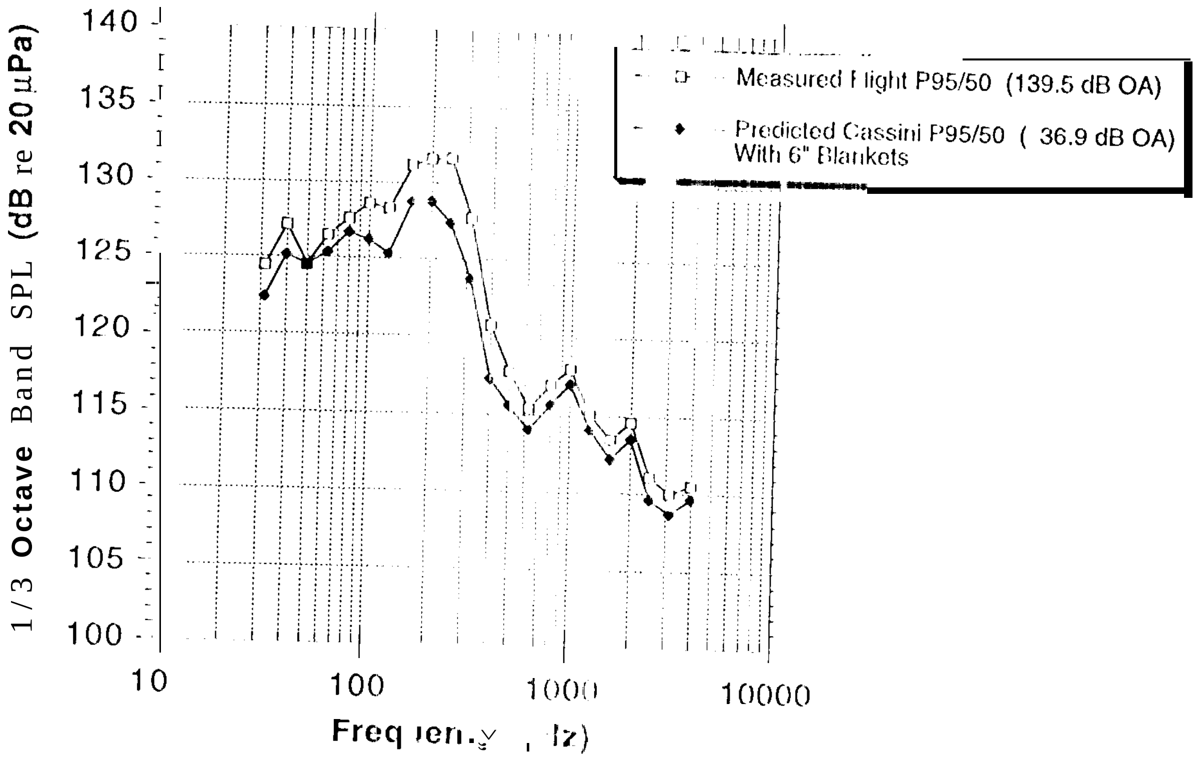


Figure 19: P95/50 Flight Spectrum Adjusted to Account for Cassini 6 in. Barrier Blankets

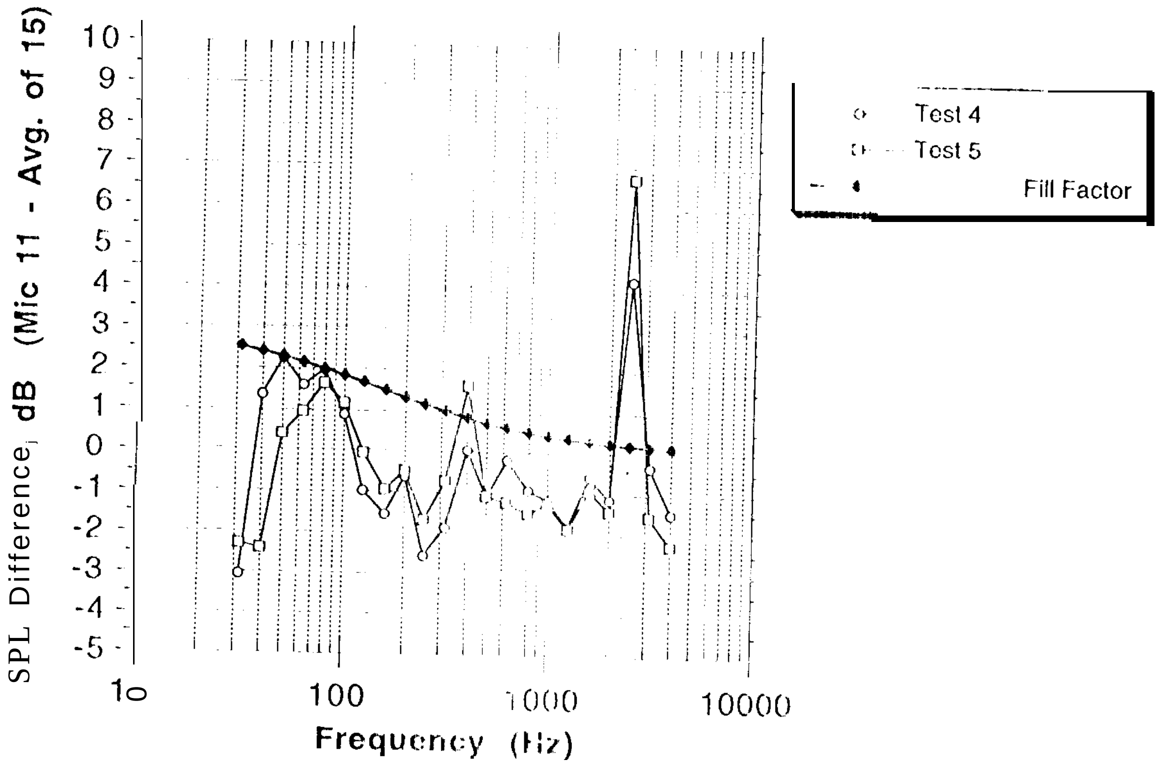


Figure 20: Analytical Fill Factor for Huygens Probe Compared to Difference of Mic 1 and Average of 15 Mics Around Spacecraft

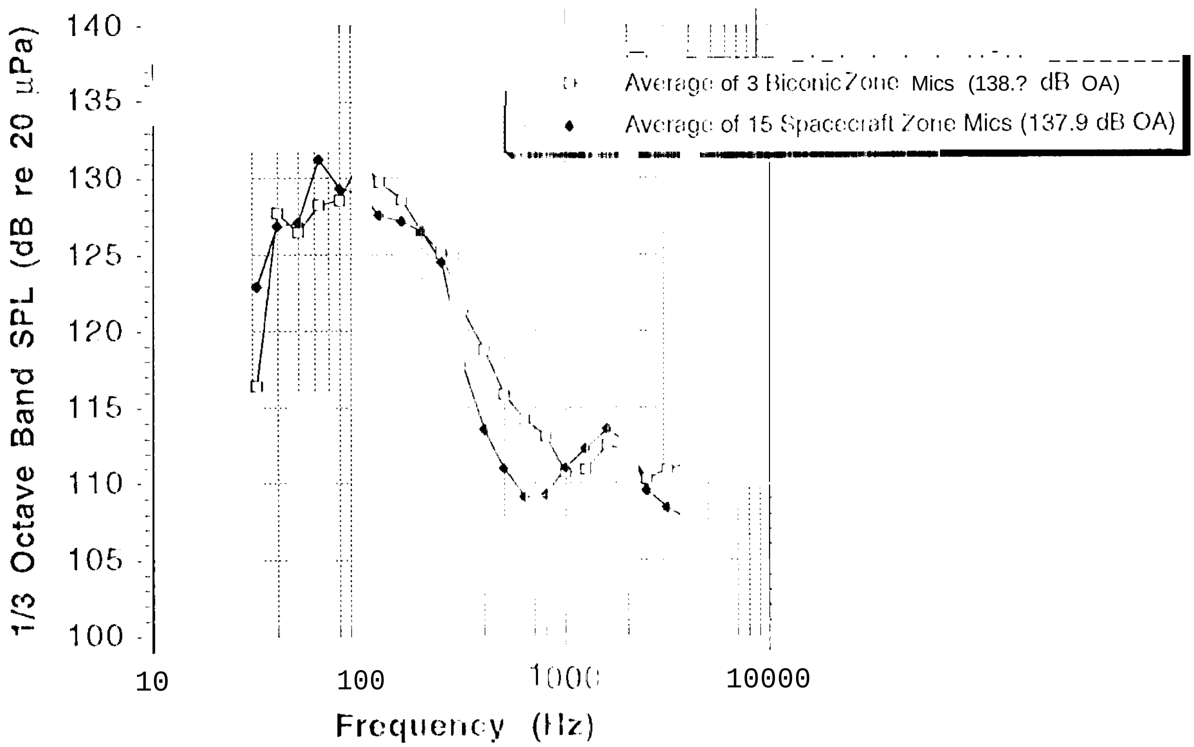


Figure 21: Comparison of Biconic and Spacecraft Zone Acoustic Spectra Measured During Test 7

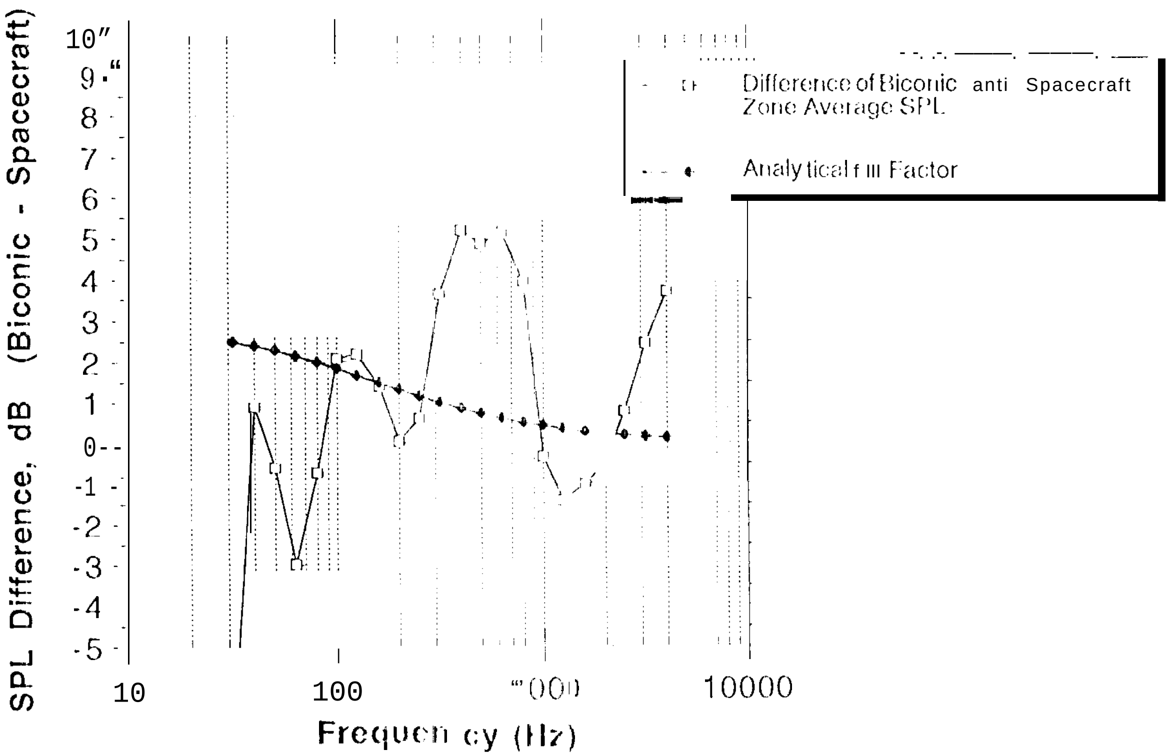


Figure 22: Difference Between Average of 3 Biconic Zone Mics and Average of 15 Spacecraft Zone Mics Plotted With Analytical HP Fill Factor

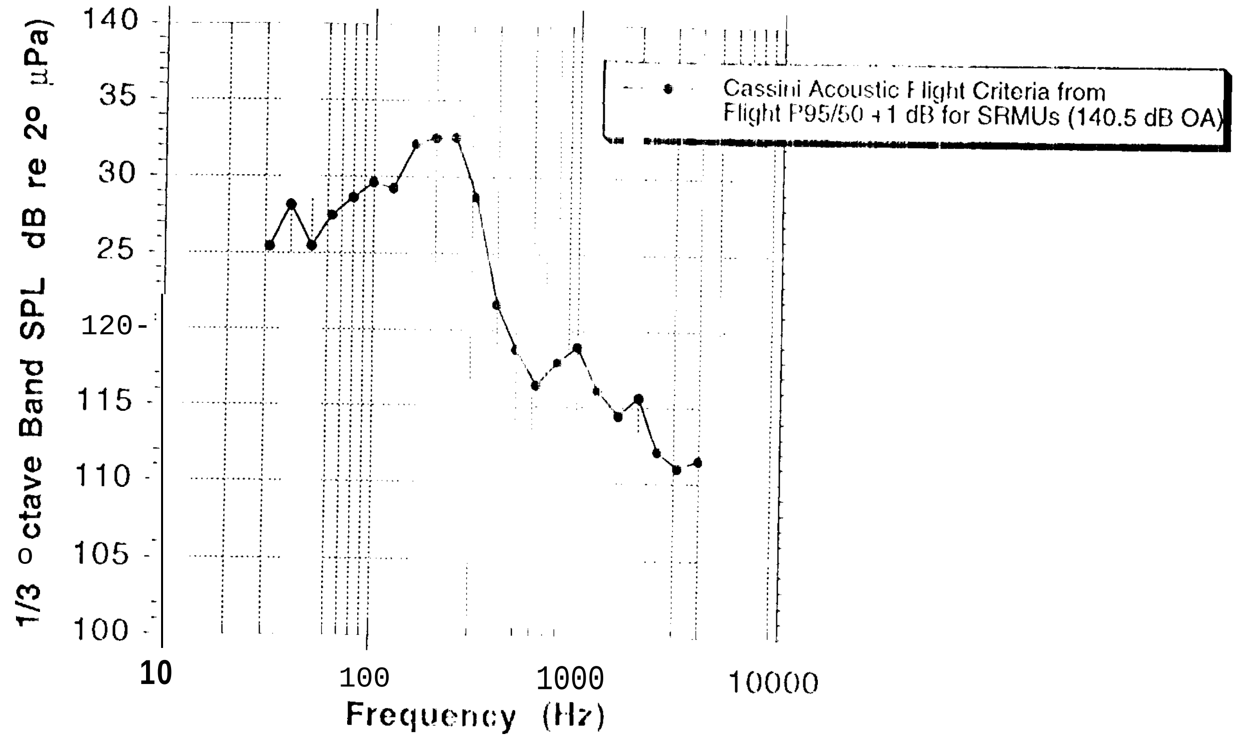


Figure 23: The Cassini Acoustic Flight Criteria

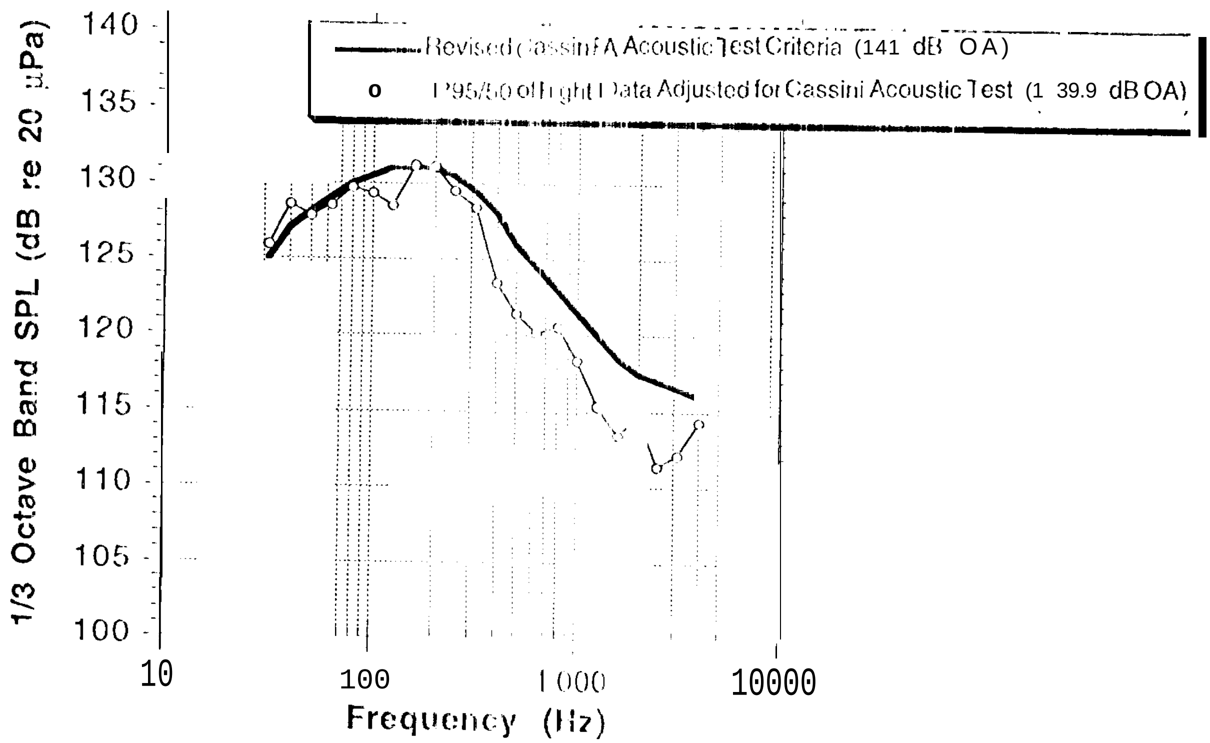


Figure 24: The Cassini Flight Acceptance Level (FA) Acoustic Test Criteria